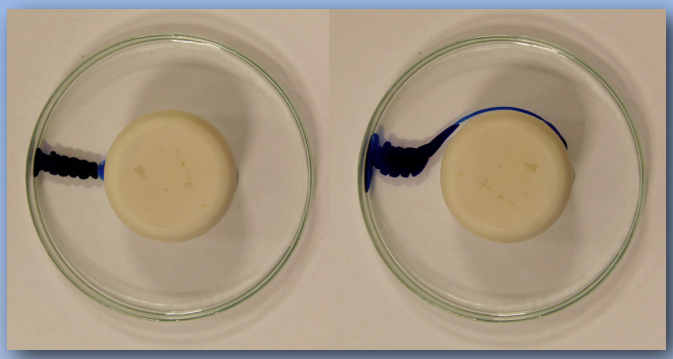
THE WAY FLUIDS BEHAVE:

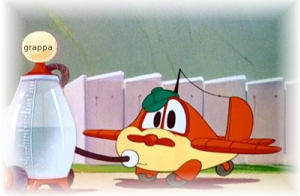
VISCOSITY AND THE "NO-SLIP" CONDITION

- **Real fluids are viscous. We can walk because of the friction between our shoes and the floor. Similarly, airplanes can fly thanks to air's viscosity (fluid's internal friction).**



- **When a fluid flows over a solid surface, a thin layer of fluid (the so called boundary layer) sticks to the surface (the so called no-slip condition). In it the relative speed of the surface and the fluid is zero. The boundary layer modifies fluid's flow by viscous stress.**
- **Air sticks to the wings of an airplane, modifying its own trajectory and generating "downwash" (air is pushed downwards).**
- **An airplane could never fly in an inviscid fluid.**

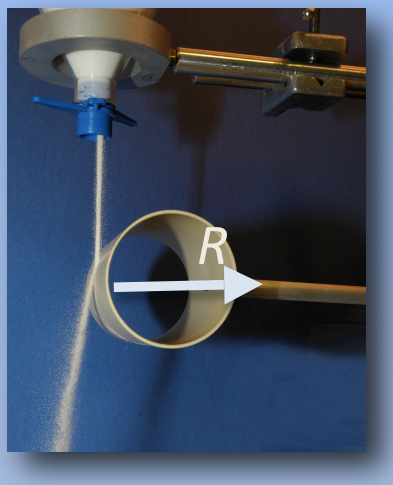
Then, why is Bernoulli's principle invoked to explain lift?



BENDING FLUIDS:

THE COANDA EFFECT

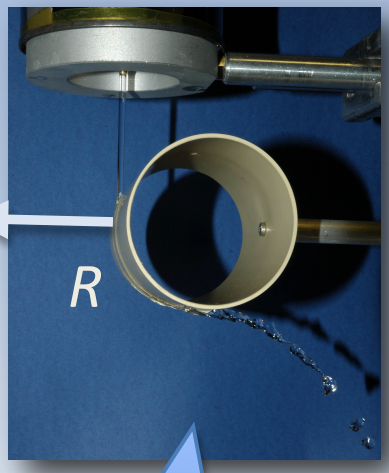
SAND



- A jet of fluid (liquid or gaseous) will stick to a curved surface and follow its profile. At the origin of the fluid's bending lays viscosity and the no-slip condition at the solid-fluid boundary. An equal and opposite reaction to the force that bends the fluid acts on the cylinder.

- Air is a fluid. Momentum exchange between air and a surface takes place through shear stress and viscosity.

Why is it stated that it is momentum exchange of air hitting the lower part of a wing to generate lift?

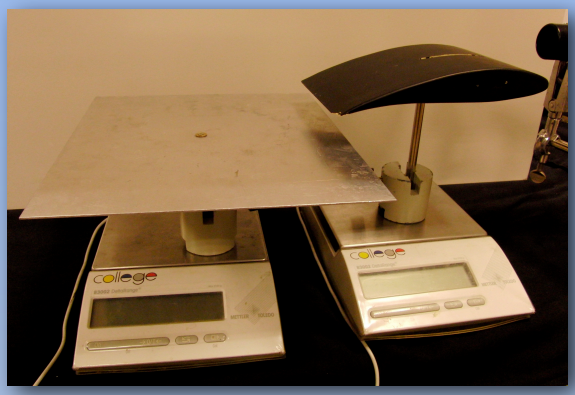


WATER

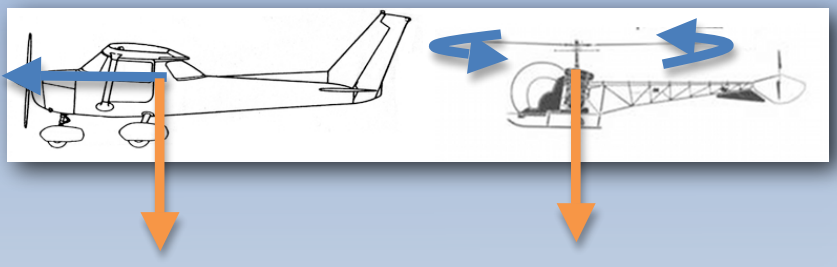
CHANGING AIR DIRECTION:

DOWNWASH AND THE LIFT FORCE

- Under appropriate conditions any solid surface will divert a flux of air. The amount of diverted air ("downwash") is directly related to the generated lifting force on the surface.

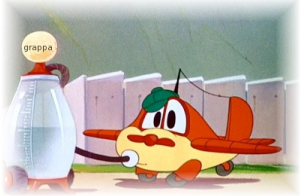


- Airplanes and helicopters divert air down for generating the needed lifting force to remain airborne. Such a force corresponds to the added contribution of the pressure field *along* the airfoil surface.



- Pressure gradient *along* an airfoil determines air's speed in the flow direction.

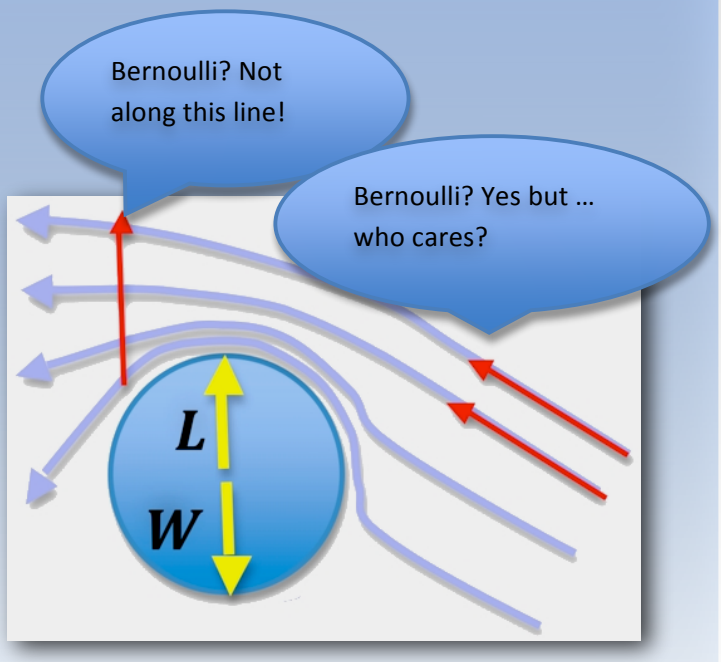
Why is it stated that pressure is lower on the top of a wing because air speeds up? And, why is it stated that air speeds to keep up with air flowing under the wing?



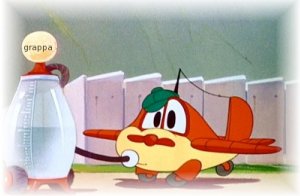
STAYING UP:

DEVIATED AIR AND LIFTING FORCES

- **Air bending at the ball's surface generates a pulling force on the ball towards the air jet.**
- **Air (which is viscous) sticks to the surface (forming the boundary layer) generating a lower pressure in the flow direction. This forces the whole jet to start adhering to the ball's profile.**
- **An equal and opposite reaction to the force that bends the jet pulls the ball towards it**
- **An ideal jet fluid cannot sustain a ball (neither an airplane).**



Then, why it is Bernoulli's principle invoked to explain levitating balls?



MISCONCEPTIONS: please be careful, do NOT trust the following statements …

- Airfoils need to be curved: **NO!**
- Air going over and under an airfoil "keeps up" to rejoin at the trailing edge (Equal transit time "Principle") : **FALSE.**
- Air speed determines the pressure field over an airfoil: **IT'S EXACTLY THE OPPOSITE.**
- Air hitting an airfoil "pushes" it up: **IT'S THE AIR ABOVE THE WING WHICH MATTERS.**
- Bernoulli's principle can be applied "everywhere" : **NO, ONLY WHERE VISCOSITY CAN BE NEGLECTED.**